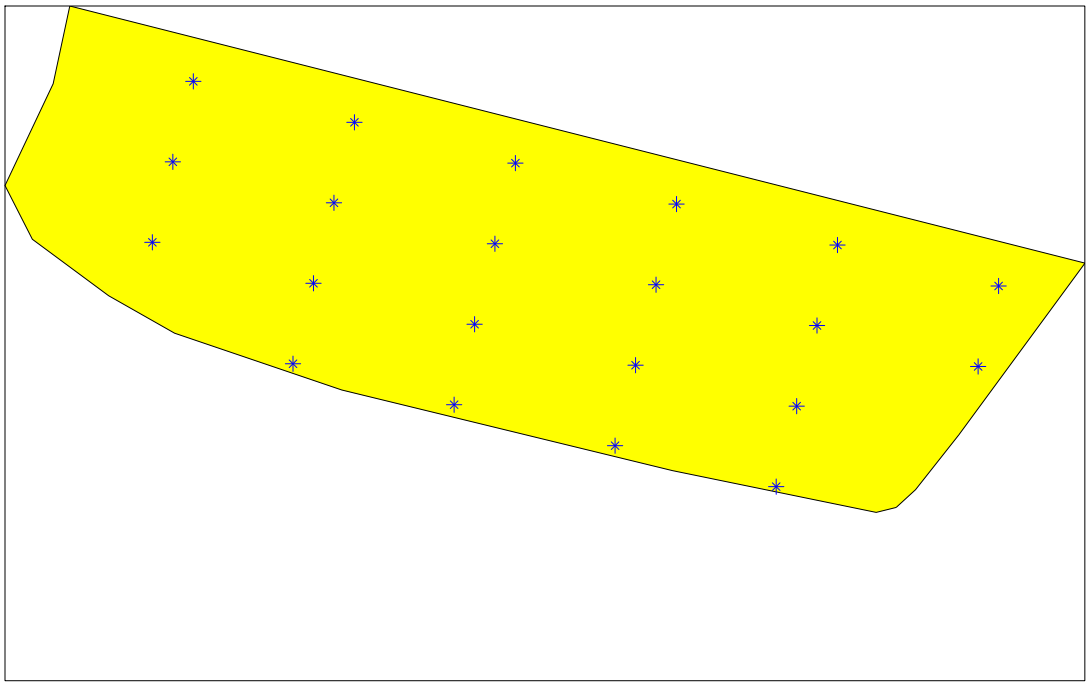
Systematic sampling locations for detecting an area of elevated values (hot spot)

This report summarizes the sampling design used, associated statistical assumptions, as well as general guidelines for conducting post-sampling data analysis. Sampling plan components presented here include how many sampling locations to choose and where within the sampling area to collect those samples. The type of medium to sample (e.g., soil, groundwater, etc.) and how to analyze the samples (in-situ, fixed laboratory, etc.) are addressed in other sections of the sampling plan.

The following table summarizes the sampling design developed. A figure that shows sampling locations in the field and a table that lists sampling location coordinates are also provided below.

SUMMARY OF SAMPLING DESIGN	
Primary Objective of Design	Detect the presence of a hot spot that has a specified size and shape
Type of Sampling Design	Hot spot
Sample Placement (Location) in the Field	Systematic (Hot Spot) with a random start location
Formula for calculating minimum size of hot spot	Algorithm developed by Singer and Wickman (1969)
Input number of samples	21
Type of samples	Point Samples
Number of samples on map [a]	21
Number of selected sample areas [b]	1
Specified sampling area [c]	2035162.35 ft^2
Grid pattern	Rectangular
Size of grid / Area of grid [d]	220.128 x 440.256 feet / 96912.5 ft^2
Total cost of sampling [e]	$11,500.00

[a] This number may differ from the calculated number because of 1) grid edge effects, 2) adding judgment samples, or 3) selecting or unselecting sample areas.
[b] The number of selected sample areas is the number of colored areas on the map of the site. These sample areas contain the locations where samples are collected.
[c] The sampling area is the total surface area of the selected colored sample areas on the map of the site.
[d] Size of grid / Area of grid gives the linear and square dimensions of the grid spacing used to systematically place samples.
[e] Including measurement analyses and fixed overhead costs. See the Cost of Sampling section for an explanation of the costs presented here.



Area: Area 1					
X Coord	**Y Coord**	**Label**	**Value**	**Type**	**Historical**
2846179.7801	2340967.0852			Hotspot	
2846606.4652	2340858.6195			Hotspot	
2847033.1503	2340750.1537			Hotspot	
2847459.8354	2340641.6880			Hotspot	
2845807.3279	2341288.8935			Hotspot	
2846234.0130	2341180.4278			Hotspot	
2846660.6981	2341071.9620			Hotspot	
2847087.3832	2340963.4963			Hotspot	
2847514.0683	2340855.0305			Hotspot	
2845861.5608	2341502.2361			Hotspot	
2846288.2459	2341393.7703			Hotspot	
2846714.9310	2341285.3046			Hotspot	
2847141.6161	2341176.8388			Hotspot	
2847568.3012	2341068.3731			Hotspot	
2847994.9863	2340959.9073			Hotspot	
2845915.7937	2341715.5786			Hotspot	
2846342.4788	2341607.1129			Hotspot	
2846769.1639	2341498.6471			Hotspot	
2847195.8489	2341390.1814			Hotspot	
2847622.5340	2341281.7156			Hotspot	
2848049.2191	2341173.2499			Hotspot	

Primary Sampling Objective
The primary purpose of sampling at this site is to detect "hot spots" (local areas of elevated concentration) of a given size

and shape with a specified probability, 1-β.

Selected Sampling Approach
This sampling approach requires systematic grid sampling with a random start. If a systematic grid is not used, the probability of detecting a hot spot of a given size and shape will be different than desired or calculated.

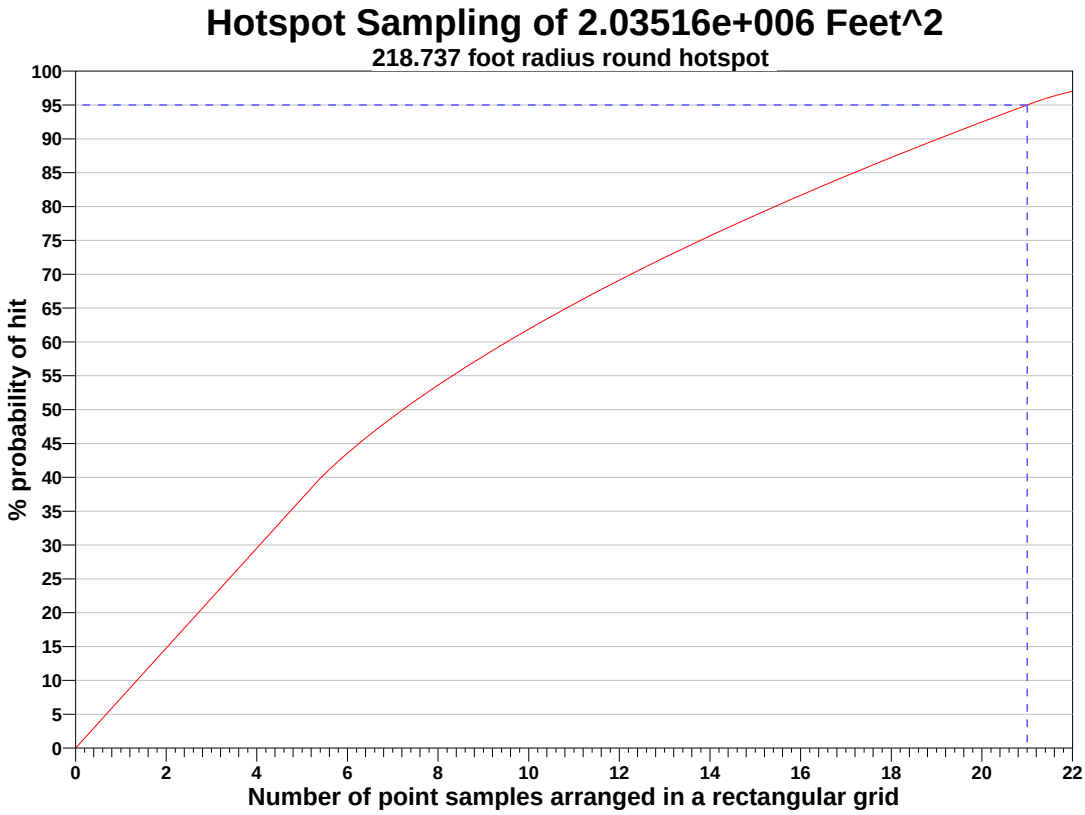
Number of Total Samples: Calculation Equation and Inputs
The algorithm used to calculate the probability of a hit (which makes possible the calculation of the hot spot size or the number of samples) was developed by Singer and Wickman (1969) and Singer (1972) with refinements by Davidson (1995). Gilbert (1987) also discussed hotspot sampling designs. Inputs to the algorithm include the size, shape, and orientation of a hot spot of interest, an acceptable probability of finding a hot spot, the desired type of sampling grid, and the sampling budget. For this design, the smallest hot spot that could be detected was calculated based on the given grid size and other parameters.

The inputs to the algorithm that result in the smallest hot spot that could be detected are:

Parameter	Description	Value
Inputs		
Samples	Number of samples specified by user	21
1-β	Probability of detection	95%
Grid Type	Grid pattern (Square, Triangular or Rectangular)	Rectangular
Rectangle Ratio	Rectangle width to height ratio	2
Grid Size	Spacing between samples	220.128 x 440.256 feet
Grid Area	Area represented by one grid	96912.5 ft^2
Sample Type	Point samples or square cells	Points
Hot Spot Shape	Hot spot height to width ratio	1
Angle	Angle of orientation between hot spot and grid	Random
Sampling Area	Total area to sample	2035162.35 ft^2
Outputs		
Hot Spot Size	Length of hot spot semi-major axis	218.737 feet
Hot Spot Area [a]	Area of hot spot (Length^2 * Shape * π)	150313 ft^2

[a] Length of semi-major axis is used by Singer-Wickman algorithm. Hot spot area is provided for informational purposes.

The following graph shows the relationship between the number of samples and the probability of finding the hot spot. The dashed blue line shows the actual number of samples for this design (which may differ from the optimum number of samples because of edge effects).



Assumptions that Underlie the VSP Locating a Hot Spot Design Method

1. In the decision area there is at least one hotspot of the designated size, which is circular or elliptical in shape.
2. The level of contamination that defines a hotspot is well defined.
3. The location of the hotspot is unknown, and if a hotspot is present, all locations within the sampling area are equally likely to contain the hotspot.
4. With a randomly determined starting location, samples are taken on a square, rectangular or triangular (equilateral) grid pattern that covers the decision area.
5. Each sample is collected, handled, measured or inspected using approved methods that yield sufficiently precise measurements.
6. A very small proportion of the surface of the decision area will be sampled. The area sampled by a single sample is much smaller than the hotspot of interest.
7. The sample methodology and sample analysis process is the same for all sample locations.
8. There are no classification errors. If a hotspot is sampled, then contamination is detected (i.e., no false negatives). If an uncontaminated area is sampled, it is not mistakenly identified as a hotspot (i.e., no false positives).

Cost of Sampling

The total cost of the completed sampling program depends on several cost inputs, some of which are fixed, and others that are based on the number of samples collected and measured. Based on the numbers of samples determined above, the estimated total cost of sampling and analysis at this site is $11,500.00, which averages out to a per sample cost of $547.62. The following table summarizes the inputs and resulting cost estimates.

COST INFORMATION			
Cost Details	**Per Analysis**	**Per Sample**	**21 Samples**
Field collection costs		$100.00	$2,100.00
Analytical costs	$400.00	$400.00	$8,400.00
Sum of Field & Analytical costs		**$500.00**	**$10,500.00**
Fixed planning and validation costs			$1,000.00

Total cost			**$11,500.00**

Recommended Data Analysis Activities
Post data collection activities generally follow those outlined in EPA's Guidance for Data Quality Assessment (EPA, 2006). The data analysts will become familiar with the context of the problem and goals for data collection and assessment. The data will be verified and validated before being subjected to statistical or other analyses. Graphical and analytical tools will be used to verify to the extent possible the assumptions of any statistical analyses that are performed as well as to achieve a general understanding of the data. The data will be assessed to determine whether they are adequate in both quality and quantity to support the primary objective of sampling.

A map of the actual sample locations will be generated so that the sampling plan and the field implementation may be compared. Deviations from planned sample locations due to topographic, vegetative, or other features will be noted. Their impacts will be qualitatively assessed. If a hot spot is discovered, additional sampling may be performed to determine its size and shape, in which case, the initial assumptions of the sampling design may then be assessed and/or reconsidered.

References
EPA 2006. *Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S*, EPA/240/B-06/003, U.S. Environmental Protection Agency, Office of Environmental Information, Washington DC.

Davidson, J.R. 1995. *ELIPGRID-PC: Upgraded Version.* ORNL/TM-13103. Oak Ridge National Laboratory, Oak Ridge, TN.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Wiley & Sons, Inc., New York, NY.

Singer, D.A. and J.E. Wickman. 1969. *Probability Tables for Locating Elliptical Targets with Square, Rectangular, and Hexagonal Point Nets*. Pennsylvania State University, University Park, Pennsylvania. Special Publication 1-69.

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